"*Study of Molecular Interaction in Some Heterocyclic Organic Compounds using Dielectric Relaxation Spectroscopy*"

A Synopsis Submitted to

Swami Ramanand Teerth Marathwada University, Nanded

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Doctor of Philosophy in Physics

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Introduction

Heterocyclic Organic Compound

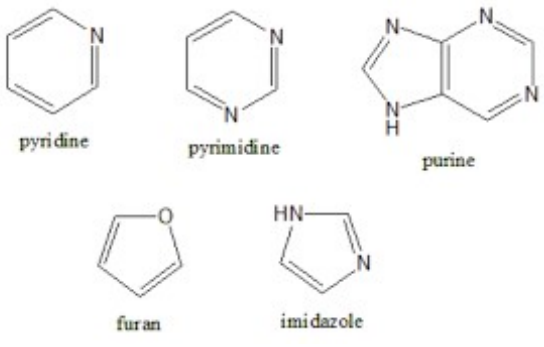
Heterocyclic organic compound is a ring structure, consisting of at least two or more than two types of atoms(elements) in its structure. Heterocyclic compound, also called **heterocycle.**

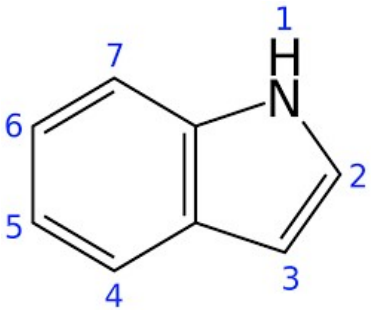
Heterocyclic organic compounds are of very much interest in our daily life. Heterocyclic compounds have one or more hetero atoms in their structure.

Heterocyclic organic compound is a major class of organic chemical compounds characterized by the fact that some or all of the atoms in their molecules are joined in rings containing at least one atom of an element other than carbon (C).

In their general structure, heterocyclic compounds resemble cyclic organic compounds that incorporate only carbon atoms in the rings—for example, cyclopropane (with a three-carbon-atom ring) or benzene (with a six-carbon-atom ring)—but the presence of the heteroatoms in its structure gives heterocyclic compounds which having physical and chemical properties that are often quite different from those of their all-carbon-ring analogs.

The most common heterocycles are those having five- or six-membered rings and containing heteroatoms of nitrogen (N), oxygen (O), or sulfur (S). The best known of the simple heterocyclic compounds are indoles, Isatin, Oxindole, Oxetanones, pyridine, pyrrole, furan, and thiophene[1-11].





Indol

Molecular Formula: Molecular formula of heterocyclic organic compound is depends on the how many number of elements present for a particular atoms.

Molecular weight : Molecular weight, also called molecular mass, mass of a molecule of a substance, based on 12 as the atomic weight of carbon-12. It is calculated in practice by summing the atomic weights of the atoms making up the substance's molecular formula.

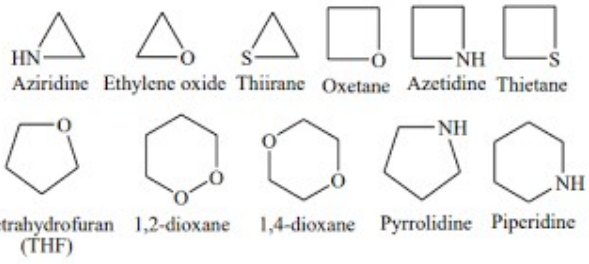
CLASSIFICATION OF HETEROCYCLIC COMPOUNDS

Based on the structural and electronic arrangement the heterocyclic compounds may be classified into two categories.

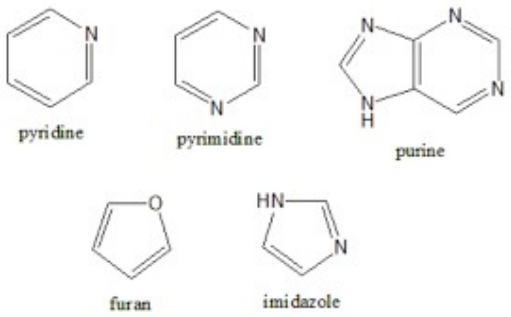
i. Aliphatic heterocyclic compounds

ii. Aromatic heterocyclic compounds

The aliphatic heterocyclic compounds are the cyclic amines, cyclic amides, cyclic ethers and cyclic thioethers. Aliphatic heterocycles those do not contain double bonds are called saturated heterocycles. The properties of aliphatic heterocycles are mainly affected by the ring strain. Examples of aliphatic heterocyclic compounds

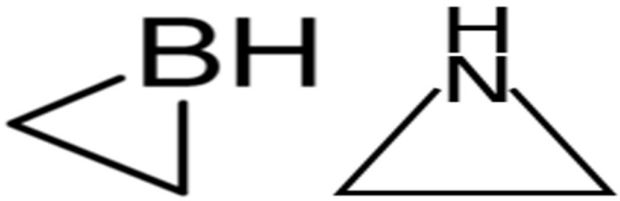


However, aromatic heterocyclic compounds are analogous of benzene. The aromatic heterocyclic compounds also follow the Huckel's rule. According to Huckel's rule an aromatic compounds must be cyclic in nature with planar geometry due to conjugate double bonds and must have $(4n+2)\pi$ electrons. Examples of aromatic heterocyclic compounds are shown below[12].



Examples of Heterocyclic Compound:

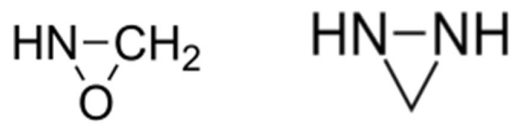
If the heterocyclic ring contain three types of atoms in it (ex. Borirane) then molecular formula C_2H_4BH Molecular weight is , 39.872 g/mol.



Borirane : C_2H_4BH **Aziridine**: $(CH_2)_2NH$

Mol. Wt. 39.872 g/mol. 43.07 g/mol

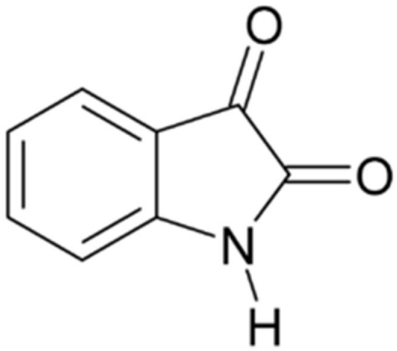
If the ring contain two hetero atoms then the molecular Formula of **Diaziridines is** CH_4N_2 , If ring contain 1 nitrogen and 1 oxygen as a hetero atom then the compound is **oxaziridine it's molecular formula is** CH_3NO



Oxaziridine : CH_3NO **Diaziridines :** CH_4N_2

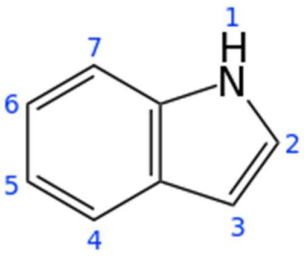
45.041 g/mol Mol. Wt. 44.057 g/ mol

Isatin : also known as **tribulin**, is an organic compound derived from indole with formula $C_8H_5NO_2$.



Isatin: $C_8H_5NO_2$ Molecular weight: 147.1308 g/mol

Indole is an aromatic heterocyclic organic compound with formula C_8H_7N [2]



Indole C_8H_7N. Molecular Weight: 117.151 g·mol^{-1}

1. Abstract of the proposed work plan/ problem:

The proposed research work is aimed at the study of dielectric relaxation and thermo physical behavior of some Heterocyclic organic compounds through their molecular interaction with solvent environment. This may be useful for getting some valuable information about structure and dynamics of systems under study using spectroscopic techniques.

Heterocyclic compounds are of very much interest in our daily life. Heterocyclic compounds have a wide range of application. They are predominantly used as pharmaceuticals, as

agrochemicals and as veterinary products. They also find applications as sanitizers, developers, antioxidants, as corrosion inhibitors, as copolymers, dye stuff.

The characterization of the dielectric properties in terms of the state of hydration, concentration, frequency and temperature, might provide useful data from which the molecular processes underlying the macroscopic results could be analysed[13] .

A conformational transformation of Heterocyclic organic compound generally leads to substantial changes of the dielectric properties which reflect the accompanying changes of overall structure. Properties of Heterocyclic organic compound is changes with temperature, solute-solvent concentration and other parameters [14]. Some Heterocyclic organic compound containing oxygen, Nitrogen, sulpher groups can enter into intra and/or intermolecular hydrogen bonding giving rise to several conformers in different solvents. Therefore, it is important to study the structural and dynamical behavior of such Heterocyclic organic compound in different solvents by changing its environment (concentration, temperature etc.).

Despite several efforts devoted to the study of investigation of structural and dynamical properties of Heterocyclic organic compound over many years, there are still many interesting aspects of molecular interaction and spectroscopic behavior, which have not been understood thoroughly.

2. Review of Literature and Development in the subject :

An important feature of the structure of many heterocyclic compounds is that it is possible to incorporate functional groups either as substituents or as part of the ring itself. For example, basic nitrogen atoms can be incorporated both as amino substituents and as part of a ring. This means that the structures are particularly versatile as a means of providing, or of mimicking a functional group. For example the uses of tetrazole ring system as a mimic of a carboxylic and functional group because of its similarity in acidity and in steric requirement. Tetrazole group is superior in

terms of metabolic stability, bioavailability and four nitrogen atoms present in the tetrazole ring can create a greater charge distribution.[15].

Khadijeh Didehban, Esmail Vessally, Mina Salary, Ladan Edjlali, Mirzaagha Babazadeh this group synthesized variety of key medicinal heterocyclic compounds *via* chemical fixation of CO_2 onto *o*-alkynylaniline derivatives in 2018[16]

Isatin, it is one the most important heterocyclic organic derivative for its pharmactical applications. The compound was first obtained by Otto Linné Erdman and Auguste Laurent in 1840 as a product from the oxidation of indigo dye by nitric acid and chromic acids[17].

Garima Mathur and Sumitra Nain recently studied on the Recent Advancement in Synthesis of Isatin as Anticonvulsant Agents in 2014[18]. After that AJMER SINGH GREWAL studied on outlines some commonly used methods to synthesize the isatin moiety and its derivatives, with advances in the use of isatin derivatives for its biological and pharmacological properties[19].

Negar Lashgari and Ghodsi Mohammadi Ziarani gives an overview of the advances in the use of isatin in the synthesis of various heterocyclic compounds via 1,3-dipolar cycloaddition reactions during the period from 2000 to 2011[20].

Tenglong Guo, Fei Huang, Likun Yu, Zhengkun Yu studied on the synthesized indole derivative of heterocyclic organic compound through transition metal-catalyzed C–H activation process in 2015[21].

Indole is derivative of heterocyclic organic compound, Indole is widely distributed in the natural environment and can be produced by a variety of bacteria. As an intercellular signal molecule, indole regulates various aspects of bacterial physiology, including spore formation, plasmid stability, resistance to drugs, biofilm formation, and virulence.

Komal B. Kabra, Kunal H. Wananje, Ashok C. Kumbharkhane, Arvind V. Sarode,recently studied The effect of microwave frequencies on the structural and dynamical properties

of heterocyclic organic compound such as Indole in the surrounding of DMSO (Dimethyl sulphoxide) molecule has been studied over the temperature region 298.15 K to 273.15 K using Time Domain Reflectometry (TDR) in the frequency region of 10 MHz–50 GHz in 2020[26].

Oxindoles are a class of hetero-aromatic organic compounds recent derivative of heterocyclic organic compound, Oxindole is a privileged scaffold for designing biological drug candidates, several oxindoles are well known for anticancer and antimicrobial activity. Oxindole derivatives are also anti-tubercular, antiviral and antirheumatic agents [22].

3. Objectives of Research/ Proposed Hypothesis

The main objective of the proposed research work is to carry out and study molecular interaction, structural and dynamical behaviour of some heterocyclic organic compounds when environment of such systems i.e. temperature, concentration, number of atoms, frequency and other parameters changes. The effect of molecular weight, temperature and concentration on heterocyclic organic compound will also be the thrust areas of this work while studying molecular behaviour and physical properties using spectroscopic techniques.

However no work on the dielectric and thermodynamic studies of heterocyclic organic compound in aqueous solution in the microwave frequency region below room temperature has been carried out. The main aim is to study the effect of temperature and concentration on the structure and dynamics of heterocyclic organic compound and intermolecular interaction between heterocyclic organic compound and solvent of the molecules in terms of various dielectric and thermodynamic parameters.

4. Methodology to be adopted:

A material in liquid state can be studied by various methods, among them spectroscopic methods are very easy, accurate and appropriate to investigate structural and dynamical properties of materials in its pure as well as in different solvent environments. Many spectroscopic techniques are available now a days to study structural and dynamical properties of materials of which few of them are listed below.

1. Acoustic / Ultrasonic Spectroscopy.

2. UV-Visible Spectroscopy.

3. Fourier Transform Infra Red (FTIR) Spectroscopy.

4. Dielectric Spectroscopy.

5. Nuclear Magnetic Resonance (NMR) Spectroscopy.

All these spectroscopic techniques explains various properties, structure and dynamics in the pure, binary, ternary or multi sample liquid mixtures such as heterocyclic organic compounds, biopolymers, organic liquids materials, polymers etc.

Various techniques are available to study the molecular interaction, structural and dynamical behavior of heterocyclic organic compound such as Fourier Transform Infra-Red (FTIR)[23, 25], X-Ray[24,25], Nuclear Magnetic Resonance (NMR) and Dielectric spectroscopy[26]. Spectroscopic techniques gives vital information about structural dynamical properties of all kinds of liquids including organic, heterocyclic, biomolecules etc. which can be useful for the development and other physical properties of substance under the study in pure as well as in aqueous form. In the present work we will use some of these techniques to obtain information on the structural, dynamical and molecular interaction in heterocyclic organic compounds,

organic compounds , polymers etc. Effect of concentration, frequency and temperature may also be included in the study[26,28].

Time Domain Reflectometry:

Time Domain Reflectometry (TDR) is used to describe a technique of observing time dependence reflection response of sample under study. H Fellner-Feldegg first developed it for measurement of loss and permittivity at very high frequency range. Time domain reflectometry is prepared to suitable fast rising pulse is applied to a transmission line, usually a co-axial line with 50Ω impedance. A co-axial line is connected to sampling device (sample holder). The schematic block diagram of the experimental setup for TDR is shown in Figure

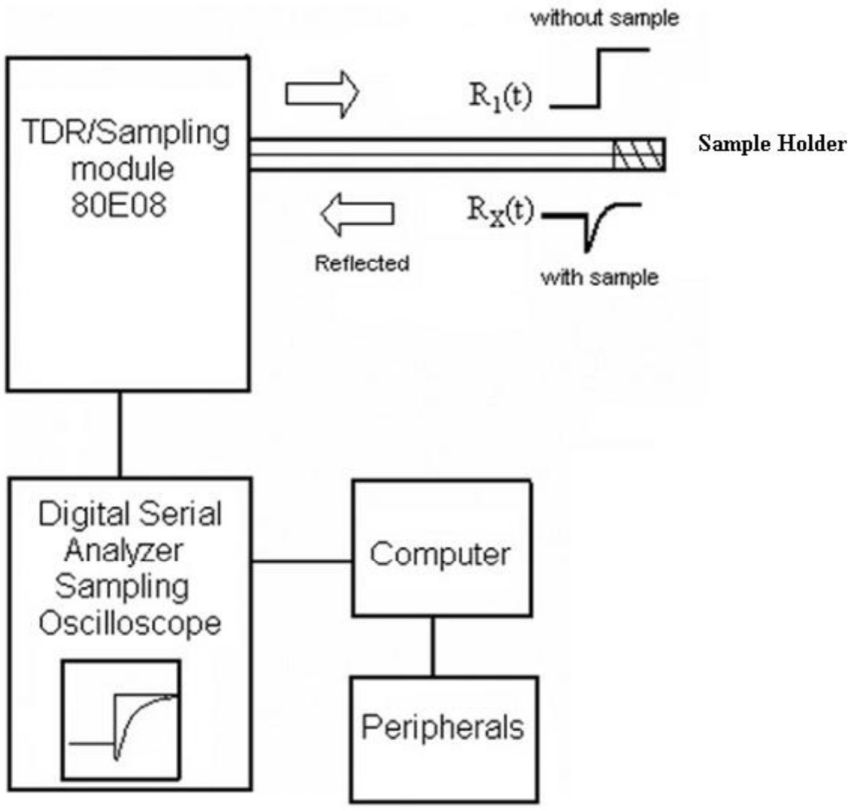


Fig.2: Schematic diagram of TDR.

In the basic TDR system a fast rising step voltage is propagated in an ideal coaxial line. The shape of step voltage remains unchanged as long as the propagation properties of the coaxial line remain

the same. The complex permittivity of sample liquid is determined through Fourier transforming of the measured step pulses in the frequency range 10 MHz to 50 GHz.

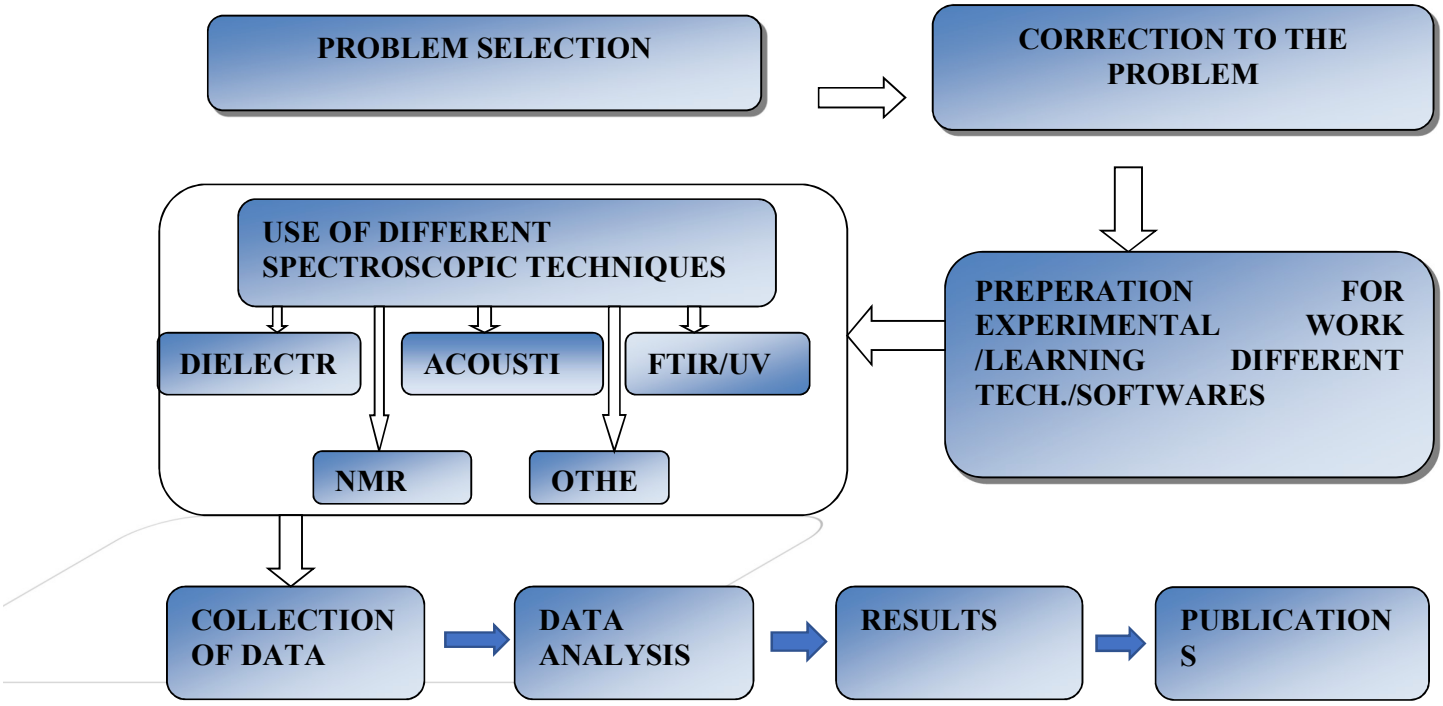
4. Importance of study/ Society application:

Heterocycles have been found a key structural in medical chemistry and also they are frequently found in large percent in biomolecules such as enzyme, vitamins, natural products and biological active compounds including antifungal, anti-inflammatory, antibacterial, antioxidant, anticonvulsant, antiallergic, enzyme inhibitors, herbicidal activity, anti-HIV, antidiabetic, anticancer activity, insecticidal agents. So that's why study of structural behaviour of heterocyclic organic compound is important for society[14].

Significance Of the Study :

The process of molecular biology generally display a high degree of specificity and efficiency unknown for simpler thermo-physical and physio-chemical phenomena. These particular properties can be attributed to appropriately evolved control and regulation mechanisms in which certain Heterocyclic organic compounds play a vital role. Such heterocyclic organic compounds usually have definite conformations which are of crucial significance for their biological function therefore it will be of the greatest importance to elucidate the nature of pertinent structures and their functional potentialities. Therefore, the study of Heterocyclic organic compound will be helpful in understanding the structural and dynamical behavior of molecules in different environment (i.e. temperature, concentration, frequency etc.) using the dielectric parameters like dielectric permittivity, dielectric constant, relaxation time and thermodynamical parameters such as entropy of activation, enthalpy of activation, free energy and many other physical parameters.

6. Proposed work Plan/ Formulation and Structure of Study:



- **Year-wise Plan of work and targets to be achieved**

Year/months	Target to be achieved
1-3 months	collection of References
4-9 months	Learning Different techniques
10-15 months	Experimental Work
16-21 months	Analysis
22-36 months	Project completion Report, Publication, Communication etc.

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